Fluctuations, Coherence And Predictability Of Long Range Shallow Water Propagation In The Straits Of Florida

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LONG TERM GOALS

Understanding long range acoustic propagation in shallow water. The coherence and predictability of long-range shallow water propagation deteriorates with higher frequency and longer range of propagation. We seek to understand the randomizing effect of fluctuations in bathymetry, sound speed and the geo-acoustic properties of the bottom. Usually, a propagating sound field is randomized after tens of kilometers of transmission but occasionally, stable and coherent signals are observed at much longer range (Monjo et al, 1997). We search for such islands of coherence in a sea of chaos.

OBJECTIVES

The research focuses on propagation in the depth to wavelength ratio D/L > 30, < 200. In this region, the wave-guide effects of the channel have a profound influence. The wave-guide determines the composition and amplitude of the individual modes and, more importantly, it controls the mode combinations and sums to produce the sound field. A broadband pulse transmission, described by perhaps hundreds of modes, yields a time arrival pattern at a receiving point that contains only a few distinct arrivals. The objective is to understand how the arrival pattern properties of coherence, fluctuations and predictability relate to the individual modes and waveguide recombination. This is an area of basic research that has not been systematically studied nor is it well understood. The immediate objective is to observe the coherence and predictability of the arrival patterns over all practical frequencies and ranges of transmission.

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APPROACH

The approach is experimental in a natural laboratory setting. The center piece is a set of three receiver arrays, two horizontal, 500 m in length, and one vertical array that is suspended in 148 m of water. A total of 96 hydrophones are processed in-situ and data are transmitted to shore via fiber optics cable. The system is engineered for a ten-year lifetime and all components can be easily raised from the seafloor for servicing and repair.

The arrays will be used to receive transmissions from a moored source. The ASREX source will be moored at each of 6 ranges tentatively set at 10,20,40,60,80 and 100 km from the receiving array. The source will then transmit m-sequences at each of 6 center frequencies, 100,200,400,800,1600,and 3200 Hz. The bandwidth is 25% of the center frequencies. The transmissions will continue for 14 days, long enough to resolve diurnal components and the spectrum of internal waves and tides. Four moorings, placed between source and receiver, will measure the temperature vs. depth profile at 12 depths to be used for the estimation of the sound speed profile. The bathymetry and geo-acoustic properties of the bottom and sub-bottom will be measure along a 7-km swath around the 148m contour between Miami and Palm Beach - a distance of 100 km. (Figure 1)

WORK COMPLETED

The principle accomplishment during the past year has been the design, engineering and installation of three, 32 element receiving arrays in 145m of water. They are connected to a shore station via fiber optic cable. The wet end has in-situ processors that are programmable from shore. Gain, filter characteristics and sampling frequency are also controlled with Linux-based computers and fiberoptic hardware.

An Environmental Impact Assessment report was completed by Mr. Bill Baxley of the South Florida Testing Facility (SFTF) (Naval Surface Warfare Center, Carderock Div) and after review, a Finding of No Significant Impact (FONSI) was issued by NAVSEA thus opening the way for acoustic propagation measurements at sea.

Instrumentation acquired using DURIP funds was prepared for the upcoming experiments. The ASREX Source was altered to include 1600 and 3200 Hz transducers.

Mooring design programs have been acquired and utilized to test and refine designs for the acoustic moorings.

Models predictions of pulse responces for the several ranges and frequencies have been completed and the corrresponding measures of pulse responses have recently begun.

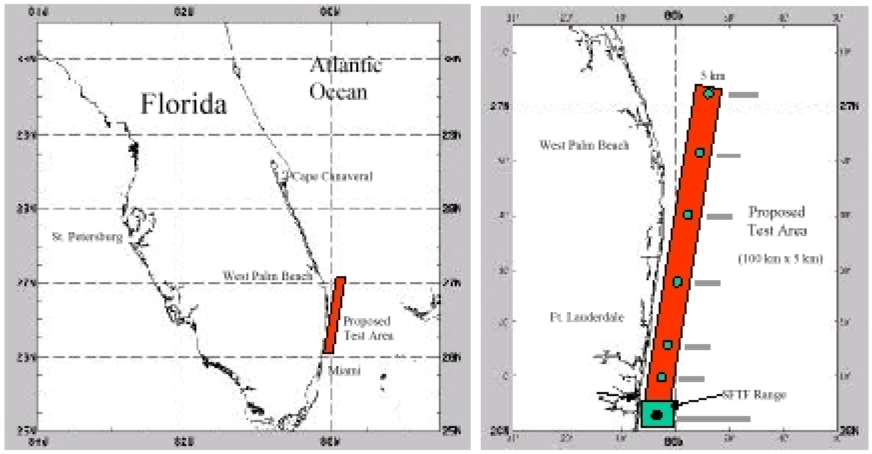


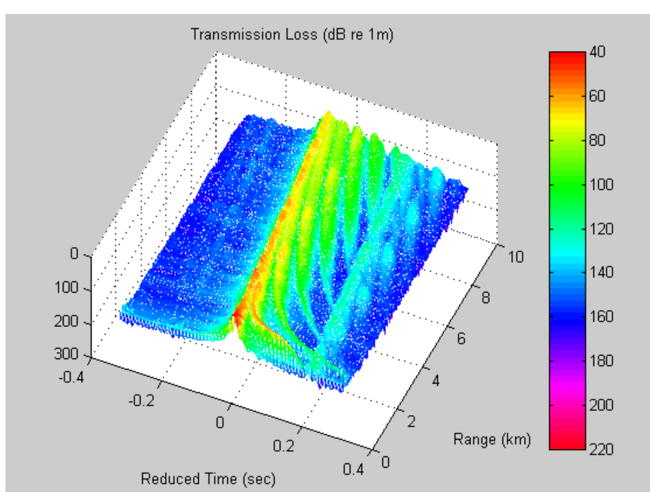
Figure 1. Site of the Florida Straits Propagation Experiments

RESULTS

Predictions of pulse responses for all frequencies and ranges show similar arrival patterns with a few distinctive features. An example is shown in figure 2 for the 800 Hz, pulse and winter sound speed profile conditions with a surface duct. Distinct and resolvable arrivals are present at all ranges. Orderly refraction patterns are resolved that can be interpreted as refracted bottom-reflected BRB paths. The total number of arrivals at the ten-km range is 5 for the winter profile compared with 4 for the summer. A focused and intense late peak is present at all ranges and is at least 20 dB higher than other arrivals.

An early arrival, from an SRBR, path is clear at all ranges. Another “extra bounce” surface arrival is appears as a late and weak double arrival. The surface duct begins to hold the 800 Hz signal and a set of early ducted arrivals are visible. These are refracted paths that are trapped near the surface, and as a result they travel in relatively fast water and arrive early. Although they are ducted near the surface they leak and permeate the entire channel and are sensed by the deep receiver. Also present are interesting and peculiar packets known as the ‘Ducted Precursors” studied by Monjo.
So far the model calculations do not include randomizing effects of the bottom or the medium. Initial comparisons with experiments will determine the ranges of transmission and frequencies over which arrival patterns are predictable with idealized models.

Figure 2. PE model prediction for 800 Hz. Pulse Transmission During Winter .



IMPACT/APPLICATIONS

One may predict with confidence that bi-static active sonar will be applied to the problem of shallow water ASW and such a system will operate in a D/L range of between 30 and 100. Also, it is nearly certain that the limiting factor in performance will be the very complicated acoustic environment. At present, a fundamental understanding is lacking about the coherence, fluctuations and predictability of acoustic signals in this important mid-frequency range. Most all previous long range propagation experiments in shallow water have concentrated on D/L's < 30. The few measures for higher D/L values reveal that most of the signal energy is contained in a small number of distinct arrivals. The one or two most intense of these arrivals are important for sonar applications since they carry most all of the signal energy and are the only signal detectable at long ranges. Also, they appear to be more stable, coherent and predictable compared with other sound field features. The research underway here will determine the signal properties for active sonar for *all practical ranges and frequencies*. Further, the natural laboratory approach defines the acoustic environment that is necessary to understand the physical processes at play.

TRANSITIONS

1) A STTR that developed from application of propagation measurements techniques has transition to Phase II funding during the past year. The concept is an expendable probe source for the clandestine observation of acoustic properties of shallow water propagation channels. A small and expendable probe source and a shipboard receiver system have been developed for the direct measurement of the acoustic transmission characteristics of shallow water sound channels. The device is 4 inches in diameter and can be deployed from the signal tube of a submarine. Once launched, the source positions itself in the water column and transmits a broadband signal that is coded for pulse compression. The coding and coherent processing produce a gain of 36 dB so that the transmission may go undetected by a listener without knowledge of the signal properties. The Submarine or AUV can then proceed to measure channel pulse response out to ranges of several tens of kilometers.

2)Engineering Acoustics Inc has partnered with University of Miami scientists in the development of advanced concept low frequency acoustics sources that can be used in basic and applied experiments on a variety of topics relevant to shallow water ASW signal processing. The compact Experimental Research (CER) source now under development, will have a source level of 192 dB//up and is slightly larger (6" by 6ft.) than the Probe Source but still much smaller than conventional research sources in use today. CER sources used orthogonal pulse compression coded so that several can be received simultaneously with a single receiver.

RELATED PROJECTS

The South Florida Ocean Measurement Center will be host to a number of oceanographic and acoustic measurements in addition to our own. This will include Dr. Mark Luther's temperature and conductivity measurements (University of South Florida), Dr. Lynn (Nick) Shay's OSCAR radar measurements of surface currents (University of Miami), Dr. John Van Leer's Cyclosonde profiling measurements, as well as acoustic and other measurements performed by Florida Atlantic University researchers. The aforementioned "Probe Source" work will also benefit from our acoustic hardware developments, modeling and environmental measurements.

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